

LUBRICATING OIL COMPOSITIONS

The present invention relates to lubricating oil compositions which suppress the formation of sludge and which have excellent storage stability, low friction  
5 properties, small pressure transmission loss, low supply pressure loss in pipe-work, and low flammability.

The "Law Concerning the Rationalisation of the Use of Energy" was enacted as a result of the Kyoto Conference on the Prevention of Global Warming (COP3).  
10 Thus, for example, some 3,500 factories world-wide have been designated "Class 1 Energy Control Designated Factories" and energy conservation in factories and businesses has proceeded. Since energy conservation also signifies a reduction of costs the problem is being  
15 tackled positively at the present time.

In Japan, it is thought that about 56% of all electrical power consumption is accounted for by the use of electric motors. Hence, considerable energy conservation in the hydraulic systems which are used to  
20 convert the electric motor output to oil pressure is required.

Hydraulic systems are distinguished in that the "oil" which is the motive power transmitting medium has low compressibility and so it is possible to use higher  
25 pressures and to increase the output with respect to the weight of a machine, and for many reasons such as the fact that the division, concentration and speed control of the motive power can be achieved easily, such oils are widely used in industrial applications.

30 The Hydraulic Fluid Handbook, page 31, published in 1985 by the Lubrication News Agency Co. Ltd., describes that the feed pressure loss in hydraulic pipe-work based

on the Bernoulli's theorem is proportional to the density of the oil both in a vacuum pipe and in a vented pipe, elbow, branch pipe or linked pipe. That is to say, the supply pressure loss can be reduced by reducing the density if the kinematic viscosity and the pipe-work are the same, and it is also shown that at the same time an improvement in flow-rate efficiency can be devised by reducing the density. Moreover, since the supply pressure loss in hydraulic pipe-work is converted to heat and sound etc., it is suggested that the generation of heat and noise are also suppressed by reducing the density. Since reduced friction also contributes to improving energy conservation, low friction properties to an extent where stick-slip does not arise in steel-steel situations is required.

Pump design and size greatly affect the efficiency of a hydraulic system. Therefore, efforts in industry have concentrated upon improving pump efficiency. Moreover, in recent years progress toward even higher pressures has been made with a view to increasing the efficiency of hydraulic energy transmission and reducing the supply pressure loss.

Hitherto, research has not focussed on fluid properties, other than those that affect the pump, for example the introduction of friction modifiers into multigrade hydraulic fluids. Indeed, in this regard industry has not developed any standard methodologies to measure the energy efficiency of a hydraulic system.

According to a scientific paper released by Degussa-Rohmax Oil Additives (Placek, Herzog, Neveu 23/01/2003) fluids with a high viscosity index (multigrade or HVI oils) have been shown to be more energy efficient than lower VI oils. Savings occur during start-up conditions due to operating viscosity being achievable at lower

temperatures. At higher temperatures (80-100°C) HVI oils again contribute to energy savings, of up to 20%, due to improved flow rate, compared with standard fluids.

5       The present invention allows energy conservation to be achieved by improving the performance of monograde hydraulic oils as the hydraulic media for increasing the efficiency of hydraulic energy transmission.

10       Accordingly, the present invention provides a lubricating oil composition comprising lubricating oil base oil, wherein said composition has a kinematic viscosity at 40°C of from 18 to 60 mm<sup>2</sup>/s, a viscosity index of from 130 to 150 and a density at 15°C of from 0.80 to 0.84 g.cm<sup>-3</sup>.

15       Japanese fire regulations were revised in June 2002 and some lubricating oil products of flash point 250°C or above were re-designated in the "Designated Flammable Material Flammable Liquid Class" and the regulations concerning their storage and management greatly relaxed. On this basis the handling costs of lubricating oil products of flash point 250°C or above has been greatly, 20       reduced and furthermore, since they have superior fire management properties as well, there is a great demand by the end users for high flash point lubricating oil products.

25       In a preferred embodiment of the present invention there is provided a lubricating oil composition in which not only has the density been reduced by about 10% when compared with the commercial industrial lubricating oil products of the same viscosity and which surprisingly has 30       an energy conserving effect, but which also has a flash point of at least 250°C as measured by JIS K 2265 by using a narrow-cut base oil.

However, the narrow-cut base oils having a high flash point for industrial lubricating oil products are very different in terms of their molecular weight distribution from the usual base oils used by those in the industry and the proportion of high molecular weight hydrocarbon components is very small. Consequently, the solubilities of lubricating oil additives which control various aspects of performance are very low and there is a disadvantage in that turbidity and precipitates are produced, and these materials cannot be used as industrial lubricating oils.

Whilst, such narrow-cut base oils have been used in recent years in automobile lubricating oils such as engine oils and automatic gear box lubricating oils, these lubricating oil products have high molecular weight ashless dispersants such as succinic acid amide-based dispersants compounded therein amounts of from 1 to 10% per 100 parts by weight and, since the various lubricating oil additives are therefore dispersed in the narrow-cut base oil, there is no particular problem with solubility.

However, the high molecular weight ashless dispersants used in the automobile lubricating oils, cannot be used in hydraulic applications even at treat rates of less than 1 %wt., e.g. 0.1 %wt., due to emulsification in the presence of water, which is an undesirable property therefor.

In the present invention, the solubility, the low friction properties and anti-rust properties when using a specified narrow-cut base oil in industrial lubricating oils with a view to increasing energy conservation and having a high flash point may be surprisingly improved by the use of a specific amine compound.

In Japanese Unexamined Patent Application Laid Open 2002-338 983, a lubricating oil composition is described where an alkylamine has been added to a lubricating oil base oil, but the amount of anti-rust agent is greatly  
5 reduced by combining the alkylamines with the anti-rust agent. As a result, the extreme pressure performance by the anti-rust agent is suppressed to the lowest level.

In Japanese Unexamined Patent Application Laid Open H8-134488, a lubricating oil composition is described  
10 where alkylamine has been added to a lubricating oil base oil. However, saturated or unsaturated linear chain alkyl groups are disclosed for the alkyl groups. Moreover, in the document an oil which has a kinematic viscosity of ISO VG10-220 (40°C) is preferred for the  
15 lubricating oil base oil.

In Japanese Unexamined Patent Application Laid Open H11-71330, a mixture of branched tertiary alkyl primary amines and a method for its production is described. This amine is said to be useful as a poly-functional  
20 additive for fuels, lubricating oils and paints, but there is no disclosure which suggests the lubricating oil base oil of the present invention.

In Japanese Unexamined Patent Application Laid Open 2001-172659, a hydraulic oil composition for shock-  
25 absorbers is described in which aliphatic amines which have C<sub>12</sub> to C<sub>14</sub> alkyl groups and/or alkenyl groups are included in a lubricating oil base oil. The lubricating oil base oil used in the document is preferably a base oil of which the minimum value of the kinematic viscosity  
30 at 40°C is preferably 8 mm<sup>2</sup>/s and more desirably 10 mm<sup>2</sup>/s, and the maximum value of the kinematic viscosity at 40°C is preferably 60 mm<sup>2</sup>/s and more desirably 40 mm<sup>2</sup>/s. It is also disclosed that from the viewpoint of minimising

as far as possible the change in the damping force the viscosity index is preferably at least 80 and more desirably at least 95.

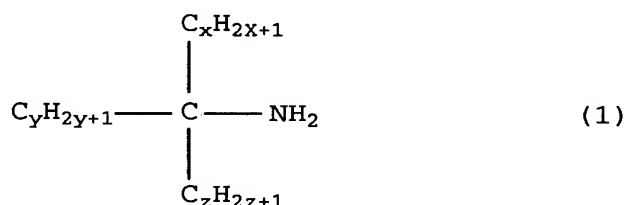
5 In Japanese Unexamined Patent Application Laid Open 2001-172660, a hydraulic oil composition for shock-absorbers where aliphatic amine which has alkyl groups and/or alkenyl groups which have from 3 to 8 carbon atoms are included in a lubricating oil base oil. The lubricating oil base oil used in the document is  
10 preferably a base oil of which the minimum value of the kinematic viscosity at 40°C is preferably 8 mm<sup>2</sup>/s and more desirably 10 mm<sup>2</sup>/s, and the maximum value of the kinematic viscosity at 40°C is preferably 60 mm<sup>2</sup>/s and more desirably 40 mm<sup>2</sup>/s. It is further disclosed that  
15 from the viewpoint of minimising as far as possible the change in the damping force the viscosity index is preferably at least 80 and more desirably at least 95.

In Japanese Unexamined Patent Application Laid Open 2002-194376, a hydraulic oil composition for shock-absorbers is described where an aliphatic primary amine  
20 the same as the amine in the present invention is compounded in a lubricating oil base oil and any lubricating oil base oil can be used provided that it is generally used as a lubricating oil base oil. The use of  
25 an oil of which the minimum value of the kinematic viscosity at 40°C is preferably 8 mm<sup>2</sup>/s and more desirably 10 mm<sup>2</sup>/s, and the maximum value of the kinematic viscosity at 40°C is preferably 60 mm<sup>2</sup>/s and more desirably 40 mm<sup>2</sup>/s is desirable. It is disclosed that  
30 from the viewpoint of minimising as far as possible the change in the damping force the viscosity index is preferably at least 80 and more desirably at least 95.

The present invention provides a lubricating oil composition with which the formation of sludge is suppressed even when the usual lubricating oil additives are compounded, which has excellent storage stability, which has low friction properties, with which the pressure transmission loss is small, with which the supply pressure loss in pipe-work is small, and which has low flammability.

In a preferred embodiment, the present invention provides a lubricating oil composition comprising lubricating oil base oil, wherein said composition has a kinematic viscosity at 40°C of from 18 to 60 mm<sup>2</sup>/s, a viscosity index of from 130 to 150, a density at 15°C of from 0.80 to 0.84 g.cm<sup>-3</sup> and a flash point of at least 220°C as measured by JIS K 2265.

In a preferred embodiment of the present invention, the lubricating oil composition may further comprise a primary amine which has a C<sub>8</sub> to C<sub>20</sub> tertiary alkyl group which can be represented by general formula (1) below



wherein x is an integer of value from 1 to 17, y is an integer of value from 1 to 17, z is an integer of value from 1 to 17, and x + y + z is an integer of value from 7 to 19.

The lubricating oil composition of the present invention may conveniently have from 0.001 to 5.0 parts by weight of the primary amine represented by general formula (1) is compounded per 100 parts by weight of the lubricating oil composition.

The present invention further provides a hydraulic oil, a machine tool oil, a gear oil, a compressor oil, a turbine oil, a bearing oil and a heat transfer fluid wherein lubricating oil additives are compounded into the lubricating oil composition of the present invention.

The lubricating oil base oil component from which the lubricating oil composition of the present invention is constituted is a base oil which comprises petroleum-based and/or synthetic hydrocarbons.

In a preferred embodiment, the lubricating oil compositions of the present invention have the same kinematic viscosity, viscosity index, density and flash point of the lubricating oil base oil because of the major effect provided by the properties of the base oil which is compounded therein.

Hence, in terms of the properties of the lubricating oil base oil used in the present invention, the kinematic viscosity at 40°C measured on the basis of the test method laid down in JIS K 2283 is generally from 18 to 60 mm<sup>2</sup>/s, preferably from 25 to 53 mm<sup>2</sup>/s, and more preferably from 28 to 51 mm<sup>2</sup>/s. If the kinematic viscosity at 40°C is higher than 60 mm<sup>2</sup>/s then even though the density is low, the supply pressure loss in hydraulic equipment pipe-work is considerable and the energy conserving performance is inevitably poor. Furthermore, if it is less than 18 mm<sup>2</sup>/s then not only is it impossible to maintain a flash point of at least 250°C, but then there are also types of equipment in which problems arise with wear resistance and this is undesirable.

Moreover, the kinematic viscosity at 40°C referred to herein corresponds to ISO VG32 and ISO VG46 in the viscosity distribution of industrial lubricating oils as defined in ISO 3448 and ASTM D 2422.



In terms of the viscosity index, a high viscosity index signifies that the temperature dependence of the lubricating oil viscosity is small and, for example, the temperature of the hydraulic oil when hydraulic equipment is first started is low and, while a hydraulic oil which has a low viscosity index will have a high viscosity, a hydraulic oil which has a high viscosity index will have a low viscosity at low temperature and it is possible to reduce the power consumption on start-up.

Here, in terms of the properties of the lubricating base oil used in the present invention, the viscosity index as defined in JIS K 2283 is generally from 130 to 150, preferably from 132 to 150 and most desirably from 135 to 150.

For example, in a case where the kinematic viscosity at 40°C is 46 mm<sup>2</sup>/s and the viscosity index is 110, the kinematic viscosity at 10°C is 283.06 mm<sup>2</sup>/s, while if the viscosity index is 130 the kinematic viscosity at 10°C is 250.1 mm<sup>2</sup>/s and if the viscosity index is 135 then it is 242.98 mm<sup>2</sup>/s and the room temperature viscosity changes markedly according to the viscosity index, and since the electrical power consumption also increases in accordance with the kinematic viscosity, a high viscosity index is also desirable for reducing the power consumption on start-up.

In the present invention, the density at 15°C of the lubricating oil base oil measured by the method for measuring the density of lubricating oil defined in JIS K 2249 is generally from 0.80 to 0.84 g.cm<sup>-3</sup>, preferably from 0.81 to 0.84 g.cm<sup>-3</sup>, more desirably from 0.815 to 0.835 g.cm<sup>-3</sup> and most desirably from 0.820 to 0.830 g.cm<sup>-3</sup>.

Moreover, hydraulic equipment generally operates at an oil temperature of from 40 to 60°C, but in the case of a density at 15°C of 0.84 g.cm<sup>-3</sup>, the density, when calculated using the density calculation method indicated in JIS K 2249, at 40°C is 0.8233 g.cm<sup>-3</sup>, at 50°C is 0.8167 g.cm<sup>-3</sup> and at 60°C is 0.8100 g.cm<sup>-3</sup>, and so the density at 40°C is preferably not more than 0.8167 g.cm<sup>-3</sup>, the density at 50°C is preferably not more than 0.8167 g.cm<sup>-3</sup> and the density at 60°C is preferably not more than 0.8100 g.cm<sup>-3</sup>.

Furthermore, since a lubricating oil composition which has low friction properties contributes to energy conservation, it is preferred that there are low friction properties such that stick-slip does not occur in steel-steel situations.

In terms of the flash point, the flash point of the lubricating oil base oil as measured using the Cleveland formula defined in JIS K 2265 is generally at least 220°C, preferably 250°C, more preferably at least 252°C, even more preferably at least 256°C.

Since the indoor parallel tolerance as laid down in JIS K 2265 is 8°C, a value of at least 258°C is most desirable for ensuring an actual flash point of at least 250°C. It is highly desirable that the flash point is 258 to 272°C, as measured by JIS K 2265.

In the Japanese fire regulations revised in June 2002, some of the conventional class 4 petroleum products with a flash point of 250°C and above were classified as designated flammable materials or flammable liquids and the dangerous material management regulations for these material were greatly relaxed and so a flash point of 250°C or above is desirable.

On the other hand, material with a flash point of 278°C or above is said to be above the dangerous material classification.

Storage stability of a lubricating oil composition is essential for providing useful performance as an industrial lubricating oil. On the other hand, troubles may arise in precision hydraulic systems, for example, in the case of lubricating oil compositions where turbidity or precipitation occurs.

Any of the petroleum-based lubricating oil base oils which have the properties outlined above can be conveniently used in the present invention. However, in general these properties cannot be realised with solvent refined base oils and ordinary hydrogenation refined base oils.

The narrow-cut base oils wherein the molecular weight distribution of the hydrocarbons in the base oil is very narrow can be cited as base oils which do satisfy these conditions.

The three types of narrow-cut base oil that may be conveniently employed in the present invention are namely:

- (1) the highly hydrogenated cracked base oils which have a viscosity index of at least 130 (typically from 145 to 155) obtained by hydro-cracking (catalytic cracking) the slack wax which is separated by solvent de-waxing as raw material in the presence of a catalyst in which the linear chain paraffins are isomerized to branched paraffins;
- (2) lubricating oil base oils which have a viscosity index is at least 130 (typically 145 to 155) obtained by producing heavy linear chain paraffins in the Fischer-Tropsch process where hydrogen and carbon monoxide obtained by the gasification process

(partial oxidation) of natural gas (methane etc.) are used and then subjecting this material to a catalytic cracking and isomerization process in the same way as described above; and

- 5 (3) the olefin oligomer synthetic hydrocarbon base oils (viscosity index at least 130) obtained by the homopolymerization or copolymerization of monomers selected from among the linear chain or branched olefin-based hydrocarbons which have from 5 to 15, and preferably from 8 to 12, carbon atoms, can be  
10 procured from the Esso Mobil Co., the BP Amoco Co., the Chevron Texaco Co. and the Fortam Co. for example.

The Fischer-Tropsch derived base oil may any  
15 Fischer-Tropsch derived base oil as disclosed in for example EP-A-776959, EP-A-668342, WO-A-9721788, WO-0015736, WO-0014188, WO-0014187, WO-0014183, WO-0014179, WO-0008115, WO-9941332, EP-1029029, WO-0118156 and WO-0157166.

20 In the present invention, these three types of narrow-cut base oil are used individually or in the form of mixtures so as to provide the prescribed viscosity.

Such narrow-cut oils also exhibit especially good volatilisation resistance. For example, when an ISO VG  
25 32 grade in the viscosity classification for industrial lubricating oils is prepared by combining these base oils, the result in a volatile loss test (NOACK) as defined in ASTM D 5800 is suppressed to 8% or less. Furthermore, the volatile loss test (NOACK) result in the  
30 case of an ISO VG 46 grade oil prepared in the same way is less than 5%. Hence, these narrow-cut base oils can also be said to be suitable for lubricating oils where involatility is required as in the case of a compressor lubricating oils for example.

Furthermore, the composition of these narrow-cut base oils is such that with the method of measurement laid down in ASTM D 3238, the aromatic content (%CA) is not more than 0.1 wt% and the paraffin content (%Cp) is at least 85 wt%, the iso-paraffin content is at least 80 wt%, the elemental sulphur content is not more than 50 ppm, the elemental nitrogen content is not more than 5 ppm, the total polar material is not more than 1% and the properties are: refractive index at least 1.45, aniline point at least 120°C and they are colourless and transparent, being classified as L0.5 using the colour test method laid down in ASTM D 1500.

The formation of sludge even on admixing the usual lubricating oil additives can be surprisingly suppressed while maintaining the excellent properties indicated above as a lubricating oil base oil by adding a primary amine compound which can be represented by general formula (1) as herein before described.

The amount of the primary amine compound represented by general formula (1) compounded in the lubricating oil composition of the present invention is preferably from 0.001 to 1.0 part by weight, preferably from 0.001 to 0.5 part by weight, and most desirably from 0.001 to 0.05 part by weight, per 100 parts by weight of the lubricating oil composition.

Examples of the aliphatic hydrocarbyl groups represented by  $C_xH_{2x+1}$ ,  $C_yH_{2y+1}$  and  $C_zH_{2z+1}$  in the above-mentioned general formula (1) include the methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group, tert-butyl group, the linear chain and branched pentyl groups, the linear chain and branched hexyl groups, the linear chain and branched heptyl groups, the linear chain and branched octyl groups, the linear chain and branched nonyl groups,

the linear chain and branched decyl groups, the linear chain and branched undecyl groups, the linear chain and branched dodecyl groups, the linear chain and branched tridecyl groups, the linear chain and branched tetradecyl groups, the linear chain and branched pentadecyl groups, the linear chain and branched hexadecyl groups and the linear chain and branched heptadecyl groups.

Actual examples of the preferred primary amine compounds which have a tertiary C<sub>8</sub> to C<sub>20</sub> alkyl group which can be used in the lubricating oil compositions of this invention include dimethylpentyl substituted methylamine, dimethyl hexyl substituted methylamine, dimethyl heptyl substituted methylamine, dimethyl octyl substituted methylamine, dimethyl nonyl substituted methylamine, dimethyl decyl substituted methylamine, dimethyl dodecyl substituted methylamine, dimethyl tetradecyl substituted methylamine, dimethyl hexadecyl substituted methylamine, methyl ethyl hexyl substituted methylamine, methyl ethyl pentyl substituted methylamine, methyl ethyl nonyl substituted methylamine, methyl ethyl undecyl substituted methylamine, diethyl hexyl substituted methylamine, diethyl butyl substituted methylamine, diethyl hexyl substituted methylamine, diethyl octyl substituted methylamine, diethyl tetradecyl substituted methylamine, dipropyl butyl substituted methylamine, dipropyl hexyl substituted methylamine, dipropyl octyl substituted methylamine, dipropyl decyl substituted methylamine, propyl dibutyl substituted methylamine, propyl butyl pentyl substituted methylamine, propyl butyl hexyl substituted methylamine, propyl butyl octyl substituted methylamine, tributyl substituted methylamine, dibutyl pentyl substituted methylamine, dibutyl hexyl substituted methylamine, dibutyl octyl substituted methylamine, tripentyl substituted

methylamine, dipentyl octyl substituted methylamine, and trihexyl substituted methylamine.

Various additives which are generally used in lubricating oil compositions can be used appropriately in the present invention.

Thus, known lubricating oil additives such as antioxidants, metal deactivators, extreme pressure additives, oil-improving agents, antifoaming agents, viscosity index improving agents, pour point depressants, cleaning dispersants, anti-rust agents and anti-emulsification agents can be added.

Examples of amine-based antioxidants include dialkyldiphenylamines such as p,p'-dioctyl-diphenylamine (such as that produced under the trade designation "Sonoflex OD-3" by the Seiko Kagaku Co.), p,p'-di- $\alpha$ -methylbenzyl-diphenylamine and N-p-butylphenyl-N-p'-octylphenylamine, monoalkyldiphenylamines such as mono-t-butyl-diphenylamine and mono-octyldiphenylamine, bis(dialkylphenyl)amines such as di-(2,4-diethylphenyl)amine and di(2-ethyl-4-nonylphenyl)amine, alkylphenyl-1-naphthylamines such as octylphenyl-1-naphthylamine and n-t-dodecylphenyl-1-naphthylamine, 1-naphthylamine, aryl-naphthylamines such as phenyl-1-naphthylamine, phenyl-2-naphthylamine, N-hexylphenyl-2-naphthylamine and N-octylphenyl-2-naphthylamine, phenylenediamines such as N,N'-diisopropyl-p-phenylenediamine and N,N'-diphenyl-p-phenylenediamine, and phenothiazines such as phenothiazine (e.g. phenothiazine, produced by the Hodogaya Kagaku Co.) and 3,7-dioctylphenothiazine.

Examples of sulphur-based anti-oxidants include dialkylsulphites such as didodecylsulphite and dioctylsulphite, thiodipropionic acid esters such as didodecylthiodipropionate, dioctadecylthiodipropionate,

dimyristylthiodipropionate and dodecyloctadecylthiodipropionate, and 2-mercapto-benzimidazole.

Examples of phenol-based antioxidants include 2-t-butylphenol, 2-t-butyl-4-methylphenol, 2-t-butyl-5-methylphenol, 2,4-di-t-butylphenol, 2,4-dimethyl-6-t-butylphenol, 2-t-butyl-4-methoxyphenol, 3-t-butyl-4-methoxyphenol, 2,5-di-t-butylhydroquinone (such as that produced under the trade designation "Anteeji DBH" by the Kawaguchi Kagaku Co.), 2,6-di-t-butyl-4-alkylphenols such as 2,6-di-t-butylphenol, 2,6-di-t-butyl-4-methylphenol and 2,6-di-t-butyl-4-ethylphenol, 2,6-di-t-butyl-4-alkoxyphenols such as 2,6-di-t-butyl-4-methoxyphenol and 2,6-di-t-butyl-4-ethoxyphenol, 3,5-di-t-butyl-4-hydroxybenzylmercaptooctylacetate, alkyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionates such as n-octadecyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate (such as that produced under the trade designation "Yoshinox SS" by the Yoshitomi Seiyaku Co.), n-butyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate and 2'-ethylhexyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate, 2,6-di-t-butyl- $\alpha$ -dimethylamino-p-cresol, 2,2'-methylenebis(4-alkyl-6-t-butylphenol) such as 2,2'-methylenebis(4-methyl-6-t-butylphenol) (such as that produced under the trade designation "Antage W-400" by the Kawaguchi Kagaku Co.) and 2,2-methylenebis(4-ethyl-6-t-butylphenol) (such as that produced under the trade designation "Antage W-500" by the Kawaguchi Kagaku Co.), bisphenols such as 4,4'-butylidenebis(3-methyl-6-t-butylphenol) (such as that produced under the trade designation "Antage W-300" by the Kawaguchi Kagaku Co.), 4,4'-methylenebis(2,6-di-t-butylphenol) (such as that produced under the trade designation "Ionox 220AH" by the Shell Japan Co.), 4,4'-bis(2,6-di-t-butylphenol), 2,2-(di-p-



hydroxyphenyl)propane (bisphenol A, produced by the Shell Japan Co.), 2,2-bis(3,5-di-t-butyl-4-hydroxyphenyl)propane, 4,4'-cyclohexylidenebis(2,6-t-butylphenol), hexamethyleneglycol-bis[3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate] (such as that produced under the trade designation "Irganox L109" by the Ciba Speciality Chemicals Co.), triethyleneglycolbis[3-(3-t-butyl-4-hydroxy-5-methylphenyl)propionate] (such as that produced under the trade designation "Tominox 917" by the Yoshitomi Seiyaku Co.), 2,2'-thio-[diethyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate] (such as that produced under the trade designation "Irganox L115" by the Ciba Speciality Chemicals Co.), 3,9-bis(1,1-dimethyl-2-[3-(3-t-butyl-4-hydroxy-5-methylphenyl)-propionyloxy]ethyl)2,4,8,10-tetraoxaspiro[5,5]undecane (such as that produced under the trade designation "Sumilizer GA80" by Sumitomo Kagaku), 4,4'-thiobis(3-methyl-6-t-butylphenol) (such as that produced under the trade designation "Antage RC" by the Kawaguchi Kagaku Co.) and 2,2'-thiobis(4,6-di-t-butylresorcinol), polyphenols such as tetrakis[methylene-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate]methane (such as that produced under trade designation "Irganox L101" by the Ciba Speciality Chemicals Co.), 1,1,3-tris(2-methyl-4-hydroxy-5-t-butylphenyl)butane (such as that produced under trade designation "Yoshinox 930" by the Yoshitomi Seiyaku Co.), 1,3,5-trimethyl-2,4,6-tris(3,5-di-t-butyl-4-hydroxybenzyl)benzene (such as that produced under trade designation "Ionox 330" by the Shell Japan Co.), bis-[3,3'-bis(4'-hydroxy-3'-t-butylphenyl)butyric acid]glycol ester, 2-(3',5'-di-t-butyl-4-hydroxyphenyl)methyl-4-(2",4"-di-t-butyl-3"-hydroxyphenyl)methyl-6-t-butylphenol and 2,6-bis(2'-hydroxy-3'-t-butyl-5'-methylbenzyl)-4-methylphenol, and p-t-butylphenol - formaldehyde

condensates and p-t-butylphenol - acetaldehyde condensates.

Examples of phosphorus-based antioxidants include triaryl phosphites such as triphenyl phosphite and  
5 tricresyl phosphite, trialkyl phosphites such as trioctadecyl phosphite and tridecyl phosphite, and tridodecyl trithiophosphite.

These antioxidants can be conveniently used individually or in the form of a combination of number of  
10 types in an amount within the range of from 0.01 to 2.0 parts by weight, per 100 parts by weight of lubricating oil composition.

Examples of metal de-activating agents which can be conveniently used in the lubricating oil composition of  
15 the present invention include benzotriazole and benzotriazole derivatives including the 4-alkylbenzotriazoles such as 4-methylbenzotriazole, 5-alkylbenzotriazoles such as 5-methylbenzotriazole and 5-ethylbenzotriazole, 1-alkylbenzotriazoles such as 1-  
20 dioctylaminomethyl-2,3-benzotriazole, and the 1-alkyltolutriazoles such as 1-dioctylaminomethyl-2,3-tolutriazole, benzimidazole and benzimidazole derivatives including 2-(alkyldithio)benzimidazoles such as 2-(octyldithio)benzimidazole, 2-(decyldithio)benzimidazole  
25 and 2-(dodecyldithio)benzimidazole and 2-(alkyldithio)-toluimidazoles such as 2-(octyldithio)toluimidazole, 2-(decyldithio)toluimidazole and 2-(dodecyldithio)toluimidazole, indazole and indazole derivatives including 4-alkylindazoles, 5-alkylindazoles  
30 and toluindazoles, benzothiazole and benzothiazole derivatives including 2-mercaptobenzothiazole (such as that produced under the trade designation "Thiolite B-3100" by the Chiyoda Kagaku Co.), 2-(alkyldithio)benzotriazoles such as 2-

(hexyldithio)benzothiazole and 2-(octyldithio)benzothiazole, 2-(alkyldithio)toluthiazoles such as 2-(hexyldithio)toluthiazole and 2-octyldithio)toluazole, 2-(N,N-

5 dialkyldithiocarbamyl)benzothiazoles such as 2-(N,N-diethyldithiocarbamyl)benzothiazole, 2-(N,N-dibutyldithiocarbamyl)benzothiazole and 2-(N,N-dihexyldithiocarbamyl)benzothiazole, and benzothiazole derivatives including 2-(N,N-

10 dialkyldithiocarbamyl)toluthiazoles such as 2-(N,N-diethyldithiocarbamyl)toluthiazole and 2-(N,N-dihexyldithiocarbamyl)toluthiazole, benzoxazole derivatives including 2-(alkyldithio)benzoxazoles such as

15 2-(octyldithio)benzoxazole, 2-(decyldithio)benzoxazole and 2-dodecyldithio)benzoxazole and 2-(alkyldithio)toluoxazoles such as 2-(octyldithio)toluoxazole, 2-(decyldithio)toluoxazole and 2-(dodecyldithio)toluoxazole, thiadiazole derivatives including 2,5-bis(alkyldithio)-1,3,4-thiadiazoles such as

20 2,5-bis(heptyldithio)-1,3,4-thiadiazole, 2,5-bis(nonyldithio)-1,3,4-thiadiazole, 2,5-bis(dodecyldithio)-1,3,4-thiadiazole and 1,2-bis(octadecyldithio)-1,3,4-thiadiazole, 2,5-bis(N,N-dialkyldithiocarbamyl)-1,3,4-thiadiazoles such as 2,5-

25 bis(N,N-diethyldithiocarbamyl)-1,3,4-thiadiazole, 2,5-bis(N,N-dibutyldithiocarbamyl)-1,3,4-thiadiazole and 2,5-bis(N,N-diocyldithiocarbamyl)-1,3,4-thiadiazole, and 2-N,N-dialkyldithiocarbamyl-5-mercapto-1,3,4-thiadiazoles such as 2-N,N-dibutyldithiocarbamyl-5-mercapto-1,3,4-

30 thiadiazole and 2-N,N-diocyldithiocarbamyl-5-mercapto-1,3,4-thiadiazole, and triazole derivatives including 1-alkyl-2,4-triazoles such as 1-dioctylaminomethyl-2,4-triazole.

These metal de-activating agents can be conveniently used individually or in the form of a combination of a number of types in an amount within the range of from 0.01 to 0.5 parts by weight, per 100 parts by weight of lubricating oil composition.

Examples of the antifoaming agents which can be conveniently used include organosilicates such as dimethylpolysiloxane, diethylsilicate and fluorosilicone, and non-silicone antifoaming agents such as polyalkylacrylates. These can be conveniently used individually or in the form of a combination of a number of types in amounts within the range of from 0.0001 to 0.1 part by weight, per 100 parts by weight of lubricating composition.

Examples of viscosity index improving agents which can be conveniently used include non-dispersing type viscosity improving agents such as polymethacrylates and olefin copolymers such as ethylene-propylene copolymers and styrene-diene copolymers, and dispersing type viscosity improving agents where nitrogen-containing monomers have been copolymerized in these materials. The amount added can be conveniently within the range of from 0 to 20 parts by weight, per 100 parts by weight of lubricating oil composition. However, when the viscosity of the lubricating oil composition is adjusted by adding a viscosity index improving agent, the flash point is inevitably lowered and so the amount of viscosity index improving agent compounded is preferably from 0 to 5 parts by weight and more desirably from 0 to 2 parts by weight, while most desirably no viscosity index improving agent is compounded at all.

Examples of the pour point depressants that may be conveniently used include polymethacrylate-based polymers. These can be conveniently used in amounts

within the range of from 0.01 to 5 parts by weight, per 100 parts of lubricating oil composition.

Examples of the cleaning dispersing agents that may be conveniently used include metal-based detergents such as neutral or basic alkaline earth metal sulphonates, alkaline earth metal phenates and alkaline earth metal salicylates, and ash-less dispersants such as alkenylsuccinimides, alkenyl succinic acid esters, and modified products derived therefrom with boron compounds and sulphur compounds for example. These can be conveniently added individually or in the form of a combination of a number of types in an amount within the range of from 0.01 to 1 part by weight, per 100 parts by weight of lubricating oil composition.

Examples of extreme pressure agents and oil-improving agents that may be conveniently used include the sulphur-based extreme pressure additives such as dialkylsulphides, dibenzylsulphide, dialkylpolysulphides, dibenzylpolysulphide, alkylmercaptans, benzothiophene and 2,2'-dithiobis(benzothiazole), and aliphatic oil-improving agents such as fatty acid amides and fatty acid esters. These extreme pressure agents and oil-improving agents can be conveniently used individually or in the form of a combination of a number of types in amounts within the range of from 0.1 to 2 parts by weight, per 100 parts by weight of lubricating oil composition.

In most cases, adequate anti-rusting performance can be realised by the addition of a lubricating oil composition of the present invention, but when a higher-level of anti-rust performance is required in accordance with the use environment, then N-alkylsarcosines, phenoxyacetic acid alkylates, imidazolines, compound produced under the trade designation "K-Corr100" by the King Industries Co., and their alkali metal salts or

amine salts, the N-acyl-N-alkoxyalkylasparaginic acid esters disclosed in Japanese Unexamined Patent Application Laid Open H6-200268 and the alkaline earth metal salts of phosphate esters disclosed in EP-A-0801116 can be conveniently used without affecting the filtration characteristics when alkaline earth metal salts are admixed. These anti-rust agents can be conveniently used individually or in the form of a combination of a number of types in amounts within the range of from 0.01 to 2 parts by weight per 100 parts by weight, of lubricating oil composition.

The known anti-emulsification agents used generally as lubricating oil additives can be conveniently used as anti-emulsification agents in the lubricating oil compositions of the present invention. They can be conveniently used in amounts within the range of from 0.0005 to 0.5 part by weight, per 100 parts by weight of lubricating oil composition.

The lubricating oil compositions of the present invention can be used as industrial lubricating oils and, in particular, as hydraulic oils. Moreover, they are also useful as heat transfer fluids, machine tool oils, gear oils, compressor oils, turbine oils, bearing oils and greases in view of their surprising ability to eliminate the pressure loss in hydraulic pipe-work.

The present invention will now be described with reference to the following examples relating to hydraulic oils which are not intended to limit the scope of the present invention in any way.

#### Examples

The base oils and additives compounded in Examples 1 to 10 and Comparative Examples 1 to 15 were as described below.

Base Oil 1: Shell XHVI™ 5.2 and Shell XHVI™ 8.2 were mixed together in proportions by weight of 56 : 44 to prepare a base oil of kinematic viscosity at 40°C of about 32 mm<sup>2</sup>/s. Shell XHVI 5.2 is the product of solvent dewaxing a Shell MDS Waxy Reffinate as obtained from Shell MDS (Malaysia) Sdn. Bld. Shell XHVI 8.2 is a mineral oil.

Base Oil 2: Shell XHVI™ 5.2 and Shell XHVI™ 8.2, as hereinbefore described, were mixed together in proportions by weight of 5 : 95 to prepare a base oil of kinematic viscosity at 40°C of about 46 mm<sup>2</sup>/s.

Base Oil 3: Poly- $\alpha$ -olefin (kinematic viscosity at 100°C of 6 mm<sup>2</sup>/s) procured from the BP Amoco Co. and a poly- $\alpha$ -olefin (kinematic viscosity at 100°C of 8 mm<sup>2</sup>/s) from the same company were mixed together in proportions by weight of 94 : 6 to prepare a base oil of kinematic viscosity at 40°C of about 32 mm<sup>2</sup>/s.

Base Oil 4: Poly- $\alpha$ -olefin (kinematic viscosity at 100°C of 6 mm<sup>2</sup>/s) procured from the BP Amoco Co. and a poly- $\alpha$ -olefin (kinematic viscosity at 100°C of 8 mm<sup>2</sup>/s) from the same company were mixed together in proportions by weight of 3 : 97 to prepare a base oil of kinematic viscosity at 40°C of about 46 mm<sup>2</sup>/s.

Base Oil 5: Solvent refined base oil (500N) and solvent refined oil (150N) classified as Group 1 as specified in Appendix E of API 1509 laid down by the American Petroleum Society were mixed together in proportions by weight of 20 : 80 to

prepare a base oil of kinematic viscosity at 40°C of about 32 mm<sup>2</sup>/s.

5 Base Oil 6: Solvent refined base oil (500N) and solvent refined oil (150N) classified similarly as Group 1 were mixed together in proportions by weight of 48 : 52 to prepare a base oil of kinematic viscosity at 40°C of about 46 mm<sup>2</sup>/s.

10 Base Oil 7: Solvent refined base oil (500N) and hydrogenation refined oil (150N) classified similarly as Group 2 were mixed together in proportions by weight of 2 : 98 to prepare a base oil of kinematic viscosity at 40°C of about 32 mm<sup>2</sup>/s.

15 Base Oil 8: Solvent refined base oil (500N) and solvent refined oil (150N) classified similarly as Group 2 were mixed together in proportions by weight of 39 : 61 to prepare a base oil of kinematic viscosity at 40°C of about 46 mm<sup>2</sup>/s.

20 Base Oil 9: Solvent refined base oil (150N) and hydrogenation refined oil (100N) classified similarly as Group 3 were mixed together in proportions by weight of 75 : 25 to prepare a base oil of kinematic viscosity at 40°C of about 32 mm<sup>2</sup>/s.

25 Base Oil 10: Solvent refined base oil (500N) and solvent refined oil (150N) classified similarly as Group 3 were mixed together in proportions by weight of 92 : 8 to prepare a base oil of kinematic viscosity at 40°C of about 46 mm<sup>2</sup>/s.

30 Amine 1: Primary amine sold under the trade designation "Primene JMT" which has C16 to C22 branched tertiary alkyl groups obtained from the Rohm and Haas Co.



Amine 2: Primary amine sold under the trade designation "Primene 81R" which has C12 to C14 branched tertiary alkyl groups obtained from the Rohm and Haas Co.

5      Amine 3: Primary amine sold under the trade designation "Primene TOA" which has C8 t-octyl groups obtained from the Rohm and Haas Co.

10      Amine 4: Primary amine sold under the trade designation "Amine T" in which a tallow component forms the alkyl group obtained from the Lion Co.

Amine 5: Primary amine sold under the trade designation "Amine CD" with a palm oil component as the alkyl group obtained from the Lion Co.

15      Amine 6: Primary amine sold under the trade designation "Amine OD" with a linear C8 alkyl group obtained from the Lion Co.

#### Other Additives

Additive 1: A mixture of 35 wt% amine-based antioxidant sold under the trade designation "Irganox L57" by the Ciba-Geigy Co., 50 wt% phenol-based antioxidant sold under the trade designation "Irganox L135" by the same company, 10 wt% anti-rust agent sold under the trade designation "Lubrizol 859" by Lubrizol Co. and 5 wt% corrosion inhibitor sold under the trade designation "Sarkosyl O" by the Ciba-Geigy Co.

25      Additive 2: A mixture of 90 wt% anti-wear agent sold under the trade designation "Lubrizol 1375" by Lubrizol Co. and 10 wt% friction-controlling agent sold under the trade designation "Emasol MO-50" by Kao Co.

30      Additive 3: A mixture of 50 wt% anti-wear agent sold under the trade designation "Reofos 65" by

5 Kao Co., 5 wt% anti-rust agent sold under the trade designation "Hitec 536" by Ethyl Co., 3 wt% of corrosion inhibitor sold under the trade designation "Sarkosyl O" by Ciba-Geigy Co., 17 wt% amine-based antioxidant sold under the trade designation "Irganox L57" by the same company and 25 wt% phenol-based antioxidant sold under the trade designation "Irganox L135" also by the same company.

10 Examples 1 to 10

Table 1

Example No.	1	2	3	4	5
Base Oil 1	98.97%				
Base Oil 2		98.97%	98.97%		
Base Oil 3				98.90%	98.97%
Base Oil 4					
Amine 1		0.03%		0.1%	0.03%
Amine 2	0.03%		0.03%		
Additive 1	1.00%	1.00%	1.00%	1.00%	1.00%
Kinematic Viscosity at 40°C (mm <sup>2</sup> /s)	31.7	46.1	46.1	31.9	31.9
Viscosity Index	150	145	145	135	135
Density at 15°C (g.cm <sup>-3</sup> )	0.826	0.833	0.833	0.831	0.831
Flash Point (°C)	252	258	258	258	258
Storage Stability	Pass	Pass	Pass	Pass	Pass
Stick-slip resistance	Pass	Pass	Pass	Pass	Pass

Table 2

Example No.	6	7	8	9	10
Base Oil 3	98.97%	98.97%		98.90%	98.10%
Base Oil 4			98.97%		
Amine 1				0.10%	0.10%
Amine 2	0.03%		0.03%		
Amine 3		0.03%			
Additive 1	1.00%	1.00%	1.00%		
Additive 2				1.00%	
Additive 3					1.00%
Kinematic Viscosity at 40°C (mm <sup>2</sup> /s)	31.9	31.9	46.1	31.9	32.1
Viscosity Index	135	135	137	135	135
Density at 15°C (g.cm <sup>-3</sup> )	0.831	0.831	0.834	0.831	0.833
Flash Point (°C)	258	258	262	258	258
Storage Stability	Pass	Pass	Pass	Pass	Pass
Stick-slip resistance	Pass	Pass	Pass	Pass	Pass

Comparative Examples 1 to 15

Table 3

Comparative Example No.	1	2	3	4
Base Oil 1	98.97%			
Base Oil 2				
Base Oil 3		98.97%	99.00%	98.97%
Base Oil 4				
Amine 4				0.03%
Amine 5	0.03%	0.03%		
Additive 1	1.00%	1.00%	1.00%	1.00%
Kinematic Viscosity at 40°C (mm <sup>2</sup> /s)	31.7	31.9	31.9	31.9
Viscosity Index	150	135	135	135
Density at 15°C (g.cm <sup>-3</sup> )	0.826	0.831	0.831	0.831
Flash Point (°C)	252	258	258	258
Storage Stability	Fail	Fail	Pass	Fail
Stick-slip resistance	Pass	Pass	Fail	Pass

Table 4

Comparative Example No.	5	6	7	8	9
Base Oil 4	98.97%				
Base Oil 5		98.97%	98.97%		
Base Oil 6				98.97%	
Base Oil 7					98.97%
Amine 1		0.03%		0.03%	0.03%
Amine 4			0.03%		
Amine 5	0.03%				
Additive 1	1.00%	1.00%	1.00%	1.00%	1.00%
Kinematic Viscosity at 40°C (mm <sup>2</sup> /s)	46.1	31.5	31.5	45.6	32.0
Viscosity Index	137	106	106	108	102
Density at 15°C (g.cm <sup>-3</sup> )	0.834	0.870	0.870	0.875	0.864
Flash Point (°C)	262	231	231	245	220
Storage Stability	Fail	Pass	Pass	Pass	Pass
Stick-slip resistance	Pass	Pass	Pass	Pass	Pass

Table 5

Comparative Example No.	10	11	12	13	14	15
Base Oil 3					98.97%	99.00%
Base Oil 7	98.97%					
Base Oil 8		98.97%				
Base Oil 9			98.97%			
Base Oil 10				98.97%		
Amine 1		0.03%		0.03%		
Amine 4			0.03%			
Amine 5	0.03%				0.03%	
Additive 1	1.00%	1.00%	1.00%	1.00%		
Additive 2					1.00%	1.00%
Kinematic Viscosity at 40°C (mm <sup>2</sup> /s)	32.0	45.9	31.9	46.0	31.9	31.9
Viscosity Index	102	107	128	127	135	135
Density at 15°C (g.cm <sup>-3</sup> )	0.864	0.867	0.841	0.847	0.831	0.831
Flash Point (°C)	220	232	242	252	258	258
Storage Stability	Pass	Pass	Pass	Pass	Fail	Fail
Stick-slip resistance	Pass	Pass	Pass	Pass	Pass	Pass

The various performance test methods used in the Examples and Comparative Examples above are outlined below.

#### Stick-slip Resistance Test

5           The sample oil was coated between steel test pieces moved at a slip rate of 12.7 mm/minute with a loading of 22.4 kgf using a stick-slip tester produced by the Cincinnati Milacron Co. (formerly ASTM D 2877) and whether or not sticking occurred was assessed in order to  
10       evaluate the low-friction - energy conserving properties of the sample oil. Lubricating oils where stick-slip occurred had a high coefficient of friction and were unsatisfactory in terms of energy conservation and therefore assessed a failure.

#### Storage Stability

15           The sample oil was introduced into a clear gloss bottle and left to stand in the dark in the open air in winter with a view to evaluating solubility, and those where there was no turbidity or precipitate formation  
20       were adjudged to have passed the test. Moreover, the open air temperature varied gradually between 5 and -5°C.

          By means of the present invention it is surprisingly possible to provide a technique for improving solubility, reducing friction and improving anti-rust properties by  
25       using a specified amine compound conjointly when using a specified narrow-cut base oil in an industrial lubricating oil.

          The lubricating oil compositions of the present invention have excellent thermal oxidation stability,  
30       lubricating properties and filtration characteristics from the viewpoint of both the safety aspects and the actual performance of the compositions.

          It will be appreciated that the kinematic viscosity at 40°C, viscosity index and density of the fluids in the

above tables are resultant from the base oil used therein.

Example 11 and Comparative Examples 16 to 18

5       The formulations tested in Example 11 and  
Comparative Examples 16-18 were as described in Table 6:

Table 6

	Example 11	Comp. Ex. 16	Comp. Ex. 17	Comp. Ex. 18
Formulation Type	Formulation according to the present invention containing 98.97 %wt. of Base Oil 4, 0.03 %wt. of Amine 2. The balance was made up of standard additive components.  ISO VG 46.	Anti-wear hydraulic oil, according to WO-A-00/63325.  Mineral-oil based (HVI).  ISO VG 68.	Synthetic biodegradable lubricant.  A commercially available ISO VG 46 environment-tally acceptable hydraulic fluid consisting of synthetic esters (HEES) and ashless additives.  Ester-based.  ISO VG 68.	Viscosity Modifier improved , multigrade hydraulic conventional anti-wear hydraulic fluid. Mineral-oil based (HVI).  ISO VG 68
VI	136	100	180	150
Kinematic Viscosity at 40 °C (mm <sup>2</sup> /s)	46.6	64.8	63.6	67.6
Density (g.cm <sup>-3</sup> )	0.8340	0.8567	0.9044	0.8598

### Test method

A suite of tests was run with a Denison PVH 57 variable displacement piston pump, at different temperatures, pressures and oil flow.

The test conditions were designed to mimic industrial applications where possible.

- Maximum 120 Bar pressure, 2500 revs min<sup>-1</sup>, 49 L min<sup>-1</sup>;
- Temperature range between 35 °C and 75 °C Maximum 120 Bar pressure;
- 2500 revs min<sup>-1</sup>, 49 L min<sup>-1</sup>;
- Vks available between 17 cSt and 100 cSt.
- Measurements of case drain (leakage) taken to calculate volumetric efficiency;
- These are at specific temperatures to simulate the use of a VG 46 fluid.

Temperature (°C)	
ISO 46	ISO 68
68	80
59	70
50	60
42	50
32	40
23	30
12	20

- A HBM torque transducer was used to take measurements of torque, along with calibrated speed and input power readings and the mechanical efficiency was calculated.

The first test assessed the effects (predicted as no effect) that the relationship between altering swash



plate angle or drive speed have on pump efficiency. The swash plate was set at different angles and then given running conditions achieved, set flow rate, speed, temperature and pressure so that the displacement of the pump was the only variable. Efficiency calculations were then performed on the data gathered and any effect was found to be below the scope of the measuring equipment, hence the relationship is assumed to be negligible.

All other tests were run by differing the drive speed, with a constant swash plate angle to maintain a constant flow.

A series of constant flow and pressure tests were be run at varied temperatures; to assess the effect of temperature on volumetric efficiency (and to a lesser extent mechanical efficiency).

#### Pump conditions

Operation of a Denison hydraulic piston pump rig used to assess hydraulic fluids and pump efficiency, including electrical fault-finding and calibration of the torque transducer. A contact box with an over-current switch controls the rig, and a dial linked to an electronic control box allows the drive shaft speed to be adjusted. Fluid temperature is varied between room temperature and 80°C. Pressure is varied between 0 Bar and 130 Bar under normal test conditions, using a manual screw-in valve.

Periodically maintenance and cleaning may be required, such as fluid changes and adjustments to the swash plate.

- Filter changes were performed between fluid changes.
- 1-litre samples of fluid were taken before and after each test.

- Vks at 40°C and 100°C, water content and cleanliness measurements were taken before and after each test.

### Overview of results

5 (N.B. The dynamic viscosity and density were measured using at Stabinger Automated viscometer at 40°C, while the other measurements are derived from Denison efficiency rig tests).

Table 7

	Example 11	Comp. Ex. 16	Comp. Ex. 18	Comp. Ex. 17
Viscosity Index	136	100	180	150
Density	0.8340	0.8567	0.9044	0.8598
Temperature (°C)	Fluid Relative Efficiency (%)	Fluid Relative Efficiency (%)	Fluid Relative Efficiency (%)	Fluid Relative Efficiency (%)
45	92.1			
50	92.3			
55	92.5	91.9	91.9	91.8
60	92.7	92.1	92	
65	92.9	92.2	92.1	91.7
70		92.3	92.2	
75		92.5	92.3	91.6

10 It is apparent from Tables 6 and 7 that the formulation of Example 11 has not only a higher VI than the conventional anti-wear hydraulic oil of Comparative Example 16, but also has a significantly lower density.

15 The above results in Table 7 show that the formulation of Example 11 surprisingly has the highest relative efficiency as the pump requires less energy per unit of fluid pumped. It would be expected in real systems where a much higher proportion of pipework exists  
20 that the benefit would be of the order of 5% or more, which could be determined by monitoring electricity consumption.

Thus, it is also surprising that in the test rig, a system dominated by the pump, the density does make a significant contribution to energy efficiency, this would not be expected according to conventional theory based on viscosity index, and may be attributed to the effect of dynamic viscosity, whereas VI is calculated from kinematic viscosity.

The present invention makes it possible to make use of narrow-cut base oils in industrial lubricating oils to increase energy conservation and raise the flash point where necessary and to provide lubricating oil compositions which, when compared with commercial industrial lubricating oils of the same viscosity, have a density reduced by some 10% and which surprisingly have an energy conserving effect.

Furthermore, the lubricating oil compositions of the present invention may be used in a wide range of industrial lubricating oils, such as hydraulic oils, machine tool oils, gear oils, compressor oils, turbine oils, bearing oils, heat transfer fluids and greases.